Draft
Report of Structure Remedial Goals and Estimated Excess Cancer Risk Relationships
Former Hunters Point Naval Shipyard, San Francisco, California

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TABLES

1 Introduction

This report describes the estimated excess cancer risks associated with remediation goals (RGs) of current structures as designated in the 2006 Action Memorandum (AM) (NAVFAC, 2006) for the former Hunters Point Naval Shipyard (HPNS) in San Francisco, California. HPNS was placed on the National Priorities List in 1989 and the Department of the Navy (DON) has been undertaking response actions under its Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) authority in each parcel. The structure RGs were derived based on limits in Regulatory Guide 1.86 (AEC, 1974) or 25 mrem/year using RESRAD-BUILD, Version 3.3. AMs before the one issued in 2006 were published in 2000 and 2001 and assumed commercial reuse scenarios only. Current structures RGs for each of the ROCs are presented in **Table 1**.

Estimations of cancer risks associated with the current HPNS RGs for each of the ROCs in structures were accomplished using current Environmental Protection Agency (EPA) methodology and EPA's Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) Calculator (available online at https://epa-bprg.ornl.gov/cgi-bin/bprg_search; last updated in May 2018), which has been modified significantly since DON issuance of the 2006 structure RGs. Use of the BPRG calculator, input parameters, and results are summarized below. BPRG calculator outputs are provided as attachments.

2 Use of the BPRG Calculator

The EPA BPRG calculator can be used with default or site-specific parameter values. Default parameter values often result in over-conservative risk estimates and are most appropriate to develop screening values. Site-specific parameter values are appropriate to more accurately estimate a site's resultant excess cancer risk to receptors and where it falls relative to the risk management range that is considered protective under CERCLA (10^{-6} to 10^{-4}). Site-specific adjustments were made to the input activity concentrations (activities), exposure time distributions, and dissipation rate constant as described in the following sections.

While using the BPRG calculator, the following options were selected:

- Select Scenario: Indoor Worker
- Select Media: Dust
- Select BPRG Type: Site-specific
  - Select Isotope Info Type: User-provided
- Select Risk Output: Yes
- Select Individual Isotopes: ROCs, see **Table 1**
- BPRG output options: select "Provide results for progeny throughout chain (with decay)"
- Hit Retrieve
- Media Concentrations: see **Section 2.1** and **Table 1**
- Indoor Worker Exposure to Settled Dust on Surfaces:
  - $ET_{iw,h}$ = 8 hr/day (see **Section 2.2**)
  - $ET_{iw,s}$= 0 hr/day (see **Section 2.2**)
  - k = 0.032 (see **Section 2.3**)
- Hit Retrieve

The Indoor Worker-Dust scenario was selected because it represents the most probable receptor exposure for activities in the remaining structures on HPNS. Indoor worker exposures result from incidental ingestion of loose dust contamination and from external exposure to loose and fixed dust on surfaces. To account for decay of the parents and progenies during the exposure period, the BPRG output option, “Provide results for progeny throughout chain (with decay)” was used for all calculations. Each exposure pathway was assessed separately with different input activities as described in Section 2.1. Input activity concentrations were adjusted using branching fractions, radon emanation factors and removable activity fractions as in **Sections 2.1.1, 2.1.2 and 2.1.3**, respectively. Adjustments to exposure time distributions and dissipation are described in **Sections 2.2 and 2.3**, respectively.

2.1 Media Concentration Adjustments

The term radionuclide refers to any nuclide that is unstable and undergoes radioactive decay. Radioactive decay is the spontaneous transformation of the unstable nuclide (parent) into one or more nuclides (daughters or progenies) with an accompanying release of energy or particles. The production of these progenies is referred to as “ingrowth.” For a given radionuclide, the rate of decay is characterized as the half-life ($T_{1/2}$) and is the average time for half of the initial radionuclide activity (in picocuries, pCi) to decay.

“Radioactivity” or, in short, “activity” (*A*), is the rate of radioactive decay, i.e., the number of nucleus transformations per unit time, and is directly proportional to the number of unstable nuclei in a source. The units of activity are curies (Ci) or becquerels (Bq). One Bq represents one disintegration (decay or transformation) per second (dps), and 1 Ci = 3.7E+10 Bq. One Ci involves a large number of transformations; therefore, a smaller unit, pCi, is often used, which is equivalent to 1E-12 Ci. Activity is also commonly reported in disintegrations per minute (dpm). Activity concentration of a radionuclide is defined as the radionuclide activity (in pCi or dpm) per area of a contaminated surface (e.g., pCi/cm^2 or dpm/100 cm^2).

Progenies can either be stable or radioactive. If the progeny is radioactive, decay will continue until a stable nuclide is reached. This series of decay is referred to as a radionuclide decay chain. In some cases, the risk from the progeny may near or exceed that of the parent and, in these cases, it is important to evaluate the ingrowth and the activities of each radionuclide in a decay chain.

To account for the ingrowth and loss of progenies, dust concentrations were adjusted using the branching fraction and radon emanation factor which are described below. In addition, for ingestion risk only, the dust concentration also is adjusted for the removable fraction of surface activity as these risks are determined only from the ingestible, or removable, portion of surface activity. For external risks, the dust concentration is only adjusted using the branching fraction and radon emanation factor. Note also that because the structure RGs are provided in units of dpm/100 cm^2, a unit conversion factor of 1 pCi/2.22 dpm was applied.

For each ROC and progeny, the media concentration entered into BPRG calculator was the product of the applicable 2006 structure RG (dpm/100 cm^2), branching fraction, radon emanation factor, removable fraction (ingestion only) and the unit conversion factor (1 pCi/2.22 dpm).

2.1.1 Branching Fraction

To allow the maximum time for ingrowth of progenies from radioactive sources containing the ROCs in Table 1, sources are assumed to have been placed into use at HPNS in 1946 with the establishment of the Radiation Laboratory, the predecessor to the Naval Radiological Defense Laboratory (NRDL). The period from 1946 to date, plus an assumed 26-year exposure period of near-term residents, is approximately 100 years. Any progeny reaching at least 10 percent of its parent's activity within this 100-year period was considered significant and was included in the pathway analysis modeling. To determine these activities, unit activities (1 pCi) for each ROC were entered in the Decay Chain Activity Projection Tool (https://rais.ornl.gov/cgi-bin/chain/chain.pl) developed by Oak Ridge National Laboratory (ORNL). Progenies are produced via a specific mode of decay of their parent radionuclides. The probability that the parent decays by that mode is called the branching fraction. For example, ^{137}Cs decays 94.7% of the time to radioactive ^{137m}Ba and only 5.3% of the time to the stable ^{137}Ba. The branching fraction of ^{137}Cs decay to ^{137m}Ba is then 0.947 and for each 1 pCi/g of ^{137}Cs, there can exist no more than 0.947 pCi/g of ^{137m}Ba. ROC and progeny branching fractions are presented in **Table 1**.

2.1.2 Radon Emanation Factor

Radon (^{222}Rn) is a progeny formed in the decay chain of ^{226}Ra. As a gas, a portion of ^{222}Rn escapes ^{226}Ra-contaminated dust into air and is lost, called radon emanation. Because of this loss, the activity of all ^{222}Rn progenies is reduced to the fraction of ^{222}Rn that remains, called the radon emanation factor, *F*. The EPA BPRG calculator does not supply a term for radon emanation. The losses are accounted for by adjusting the input concentrations of the ^{226}Ra chain. In structures, *F* for radon is 0.4 (40%) as reported in EPA (2014) (Question #17).

Similarly, Thoron, or Radon-220 (^{220}Rn), is a progeny formed in the decay chain of ^{232}Th. As a gas, a portion of ^{220}Rn escapes a ^{232}Th-contaminated dust and is lost, such that the activity of all ^{220}Rn progenies is reduced to the fraction of ^{220}Rn that remains. The losses are accounted for by adjusting the input concentrations of the ^{226}Ra chain. In structures, *F* for thoron is 0.02 (2%) as reported in EPA (2014) (Question #17). Progeny emanation factors are presented in **Table 1**.

2.1.3 Removable Fraction

Total radionuclide activity on surfaces is typically comprised of both fixed and removable contamination. The portion in each area that is removable, transferable, smearable or loose under normal working conditions is the removable fraction. While the total surface activity contributes to receptor external exposure risks, only the removable activity contributes to their ingestion risks. The 2006 structure RGs are the total activity (sum of fixed and removable) RGs with the removable fraction RG being limited to 20% of the total RG. Two concentrations are therefore presented in **Table 1** as input to the BPRG calculator, one to determine ingestion risks and the other to determine external exposure risks.

2.2 Exposure Time Adjustment

In an 8-hour work day, the BPRG calculator assumes an indoor worker is exposed to contaminated dust on soft surfaces (e.g., carpets or rugs) and on hard surfaces (e.g., concrete, tile or wood) for four hours each. All soft surfaces in HPNS structures have, or will be, removed so there is no exposure to contaminated soft surfaces. To maintain the same total eight hours of exposure, the exposure time to soft surfaces was added to that for hard surfaces. As a result:

- Exposure time, indoor worker-hard ($ET_{iw,h}$) = 8 hr/day
- Exposure time, indoor worker-soft ($ET_{iw,s}$) = 0 hr/day

Table 1. Radionuclide Activities Inputs to EPA BPRG Calculator

ROC	Progeny	2006 Structures RG (dpm/100 cm^2)	Branching Fraction	Radon Emanation Factor	BPRG Ingestion Input Activity (Dust Concentration) (pCi/cm^2) [1]	BPRG External Exposure Input Activity (Dust Concentration) (pCi/cm^2) [2]
Americium (Am)-241 (^{241}Am)		100	1		0.0901	0.4505
Cesium (Cs)-137 (^{137}Cs)		5,000	1		4.505	22.52
	Barium (Ba)-137 (^{137m}Ba)	5,000	0.944		4.252	21.26
Cobalt (Co)-60 (^{60}Co)		5,000	1		4.505	22.52
Europium (Eu)-152 (^{152}Eu)		5,000	1		4.505	22.52
Eu-154 (^{154}Eu)		5,000	1		4.505	22.52
Tritium, H-3 (^{3}H)		5,000	1		4.505	22.52
Plutonium (Pu)-239 (^{239}Pu		100	1		0.0901	0.4505
	Uranium (U)-235m (^{235m}U)	100	0.997		0.0898	0.4489
Radium (Ra)-226 (^{226}Ra)		100	1		0.0901	0.4505
	Radon (Rn)-222 (^{222}Rn)	100	1		0.0901	0.4505
	Polonium (Po)-218 (^{218}Po)	100	1	0.4	0.0360	0.1802
	Lead (Pb)-214 (^{214}Pb)	100	1	0.4	0.0360	0.1802
	Bismuth (Bi)-214 (^{214}Bi)	100	1	0.4	0.0360	0.1802
	Polonium (Po)-214 (^{214}Po)	100	1	0.4	0.0360	0.1802
	Lead (Pb)-210 (^{210}Pb)	100	0.926	0.4	0.0334	0.1668
	Bismuth (Bi)-210 (^{210}Bi)	100	0.926	0.4	0.0334	0.1668
	Polonium (Po)-210 (^{210}Po)	100	0.926	0.4	0.0334	0.1668

Table 1 (continued). Radionuclide Activities Inputs to EPA BPRG Calculator

ROC	Progeny	2006 Structures RG (dpm/100 cm^2)	Branching Fraction	Radon Emanation Factor	BPRG Ingestion Input Activity (Dust Concentration) (pCi/cm^2) [1]	BPRG External Exposure Input Activity (Dust Concentration) (pCi/cm^2) [2]
Strontium (Sr)-90 (^{90}Sr)		1,000	1		0.9009	4.505
	Yttrium (Y)-90 (^{90}Y)	1,000	0.998		0.8991	4.496
Thorium (Th)-232 (^{232}Th)		36.5	1		0.0329	0.1644
	^{228}Ra	36.5	1		0.0329	0.1644
	Actinium (Ac)-228 (^{228}Ac)	36.5	1		0.0329	0.1644
	^{228}Th	36.5	1		0.0329	0.1644
	^{224}Ra	36.5	1		0.0329	0.1644
	^{220}Rn	36.5	1		0.0329	0.1644
	^{216}Po	36.5	1	0.01	0.0007	0.0033
	^{212}Pb	36.5	1	0.01	0.0007	0.0033
	^{212}Bi	36.5	1	0.01	0.0007	0.0033
	^{212}Po	36.5	1	0.01	0.0004	0.0021
	Thallium (Tl)-208 (^{208}Tl)	36.5	1	0.01	0.0002	0.0012
Uranium (U)-235 (^{235}U)		488	1		0.4396	2.198
	^{231}Th	488	1		0.4396	2.198

[1] BPRG ingestion dust input activity (pCi/cm^2) = 2006 Structures RG (dpm/100 cm^2) x branching fraction x radon emanation factor x removable fraction (0.20) x pCi/2.22 dpm

[2] BPRG external exposure dust input activity (pCi/cm^2) = 2006 Structures RG (dpm/100 cm^2) x branching fraction x radon emanation factor x pCi/2.22 dpm

2.3 Dissipation Rate Adjustment

Surface dust concentrations, both the fixed and removable portions, decrease over time from cleaning, wear and transfers to skin or clothing. These source term losses are quantified with the dissipation rate constant, *k*. The default value in the BPRG calculator for *k* is 0.0 year^{-1} which assumes the dust source is replenished from an infinite source reservoir after each loss (dissipation). However, contaminated dust is not replenished in HPNS structures since radiological operations have been ceased for a significant period. The amount of contaminated dust lost per year was estimated from measurements of alpha contamination in Building 5/5A at Alameda Point, Alameda, California (NAVFAC, 2018). During final status surveys (FSS), Aptim Federal Services, LLC (Aptim) measured alpha surface activities at several locations on concrete floors and walls both before and after treatment with a strippable coating or with paint thinner. Treatments involving other methods (e.g., scabbling) were considered aggressive, not representative of normal cleaning and wear events at HPNS and were not included. The common ROCs between HPNS and the Building 5/5A FSS include ^{137}Cs, ^{90}Sr and ^{226}Ra. Measurements included one-minute readings at systematic locations both before and after treatment. The difference between the pre- and post-treatment results is the amount of activity removed. The percentage of activity removed is the treatment effectiveness and, for these purposes, was considered the maximum amount of activity that could be removed from that location and still be representative of the constant *k*. To be conservative, the mean treatment effectiveness (80.1%) was divided by the total exposure period of 25 years to yield a site-specific value of k = 0.032 yr^{-1}. This assumes that a regular, annual amount of cleaning or wear on a given surface would cumulatively result in the same amount of surface dust as a single, targeted treatment. The draft FSS results and summary statistics used to derive *k* are presented in **Table 2**.

Table 2. Pre-and Post-Treatment Results for Concrete Floors and Walls (NAVFAC, 2018)

Survey Unit	Location Number	Surface Type	Pre-treatment Alpha Activity (dpm/100 cm^2)	Post-treatment Alpha Activity (dpm/100 cm^2)	Removed Alpha Activity (dpm/100 cm^2)	Removed Alpha Activity (%)
82	9	Concrete floor	403.5	87.7	315.8	78.3
82	10	Concrete floor	403.5	157.9	245.6	60.9
83	18	Concrete floor	315.8	70.2	245.6	77.8
86	9	Concrete wall	877.2	122.8	754.4	86.0
100-1	6	Concrete wall	283.3	33.3	250.0	88.2
100-1	13	Concrete wall	250.0	0	250.0	100.0
100-2	5	Concrete floor	250.0	50.0	200.0	80.0
100-2	24	Concrete wall	266.7	83.3	183.4	68.8
110	9	Concrete wall	363.3	36.4	326.9	90.0
110	13	Concrete wall	436.4	127.3	309.1	70.8
					Minimum	60.9
					Maximum	100.0
					Median	79.1
					Mean	80.1

3 Estimated Risks at the 2006 Structures Remediation Goals

The resultant excess cancer risks for each ROC, progeny and exposure pathway are presented in **Table 3,** were they to be present at the RG under the aforementioned conditions. For each radionuclide chain, the total excess cancer risk is the sum of risks from each pathway and each radionuclide. The total risks fall within, or below, the risk management range for each ROC modeled at the 2006 structure RG. Note that the RGs are exclusive of (i.e., do not include) radionuclide-specific background concentrations.

Table 3. Estimated Excess Cancer Risks at the 2006 Structures Remediation Goals

ROC	Progeny	Ingestion Risk	External Exposure Risk	Total Risk
^{241}Am		1.02E-05	3.24E-08	1.0E-05
^{137}Cs		1.38E-04	3.73E-08	
	^{137m}Ba	0	1.25E-11	
Total ^{137}Cs		*1.38E-04*	*3.73E-08*	*1.4E-04*
^{60}Co		1.22E-05	5.66E-05	6.9E-05
^{152}Eu		9.22E-06	5.12E-05	6.0E-05
^{154}Eu		1.11E-05	4.18E-05	5.3E-05
^{3}H		1.38E-07	0	1.4E-07
^{239}Pu		1.38E-05	3.64E-10	
	^{235m}U	1.84E-18	0	
Total ^{239}Pu		*1.38E-05*	*3.64E-10*	*1.4E-05*
^{226}Ra		3.34E-05	1.10E-08	
	^{222}Rn	0	3.75E-13	
	^{218}Po	0	1.28E-21	
	^{214}Pb	2.96E-14	4.65E-13	
	^{214}Bi	1.47E-14	1.99E-12	
	^{214}Po	0	1.58E-23	
	^{210}Pb	1.76E-05	7.81E-10	
	^{210}Bi	1.25E-10	2.51E-12	
	^{210}Po	1.33E-06	1.25E-13	
Total ^{226}Ra		*5.23E-05*	*1.18E-08*	*5.2E-05*
^{90}Sr		4.40E-05	4.97E-09	
	^{90}Y	3.50E-09	1.25E-10	
Total ^{90}Sr		*4.40E-05*	*5.10E-09*	*4.4E-05*
^{232}Th		3.53E-06	2.10E-10	
	^{228}Ra	8.79E-06	9.04E-11	
	^{228}Ac	1.45E-12	2.00E-11	
	^{228}Th	2.94E-07	1.35E-10	
	^{224}Ra	2.04E-09	3.37E-12	
	^{220}Rn	0	3.71E-17	
	^{216}Po	0	4.70E-23	
	^{212}Pb	8.15E-13	1.13E-13	
	^{212}Bi	2.61E-15	8.55E-15	
	^{212}Po	0	0	
	^{208}Tl	0	4.37E-15	
Total ^{232}Th		*1.26E-05*	*4.59E-10*	*1.3E-05*
^{235}U		2.74E-05	1.20E-06	
	^{231}Th	8.48E-11	1.80E-11	
Total ^{235}U		*2.74E-05*	*1.20E-06*	*2.9E-05*

4 Summary

This report describes the estimated excess cancer risks associated with exposures to radionuclide-contaminated surfaces, at the former HPNS. The excess cancer risks (**Table 3**) from indoor worker exposures to surfaces contaminated with dust at concentrations equal to the 2006 structure RGs are demonstrated to be within, or below, the CERCLA risk management range of 10^{-4} to 10^{-6}.

5 References

Naval Facilities Engineering Command (NAVFAC), Southwest. 2018. *Draft – Final Status Survey Report, Building 5/5A, Alameda Point, Alameda, California*. February.

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Atomic Energy Commission (AEC). 1974. Regulatory Guide 1.86. *Termination of Operating Licenses for Nuclear Reactors*. June.

Attachments

EPA BPRG Calculator ingestion output for ^{241}Am, ^{60}Co, ^{152}Eu, ^{154}Eu and ^{3}H: *IW_bprg_26OCT2018_bprg9237_Am Co Eu H ingestion RG k=0.032.pdf*

EPA BPRG Calculator external exposure output for ^{241}Am, ^{60}Co, ^{152}Eu, ^{154}Eu and ^{3}H: *IW_bprg_26OCT2018_bprg9237_Am Co Eu H external RG k=0.032.pdf*

EPA BPRG Calculator ingestion output for ^{137}Cs, ^{239}Pu, ^{90}Sr and ^{235}U : *IW_bprg_26OCT2018_bprg9237_Cs Sr Pu U ingestion RG k=0.032.pdf*

EPA BPRG Calculator external exposure output for ^{137}Cs, ^{239}Pu, ^{90}Sr and ^{235}U : *IW_bprg_26OCT2018_bprg9237_Cs Sr Pu U external RG k=0.032.pdf*

EPA BPRG Calculator ingestion output for ^{226}Ra: *IW_bprg_26OCT2018_bprg9237_Ra ingestion RG k=0.032.pdf*

EPA BPRG Calculator external exposure output for ^{226}Ra: *IW_bprg_26OCT2018_bprg9237_Ra external RG k=0.032.pdf*

EPA BPRG Calculator ingestion output for ^{232}Th: *IW_bprg_26OCT2018_bprg9237_Th ingestion RG k=0.032.pdf*

EPA BPRG Calculator external exposure output for ^{232}Th: *IW_bprg_26OCT2018_bprg9237_Th external RG k=0.032.pdf*